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Solute- and alkali-rich supercritical fluids enhance Zr transfer from slab to wedge

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Zirconium and other HFSEs were usually thought fluid-immobile due to their extremely low solubility in dilute aqueous fluids. However, ubiquitous dissolution and re-deposition of zircon in metamorphic rocks, presence of zircon in orogenic peridotites and high Zr contents in primitive arc basalts relative to MORBs provide compelling evidence that Zr are soluble and transportable in subduction zone fluids. Supercritical fluids represent solute-rich fluids derived from deep subduction and thus may serve as effective agents for the transfer of Zr in subduction zones. However, under what conditions supercritical fluids are favorable to the transfer of Zr from slab to wedge is unclear. Here, we determined zircon solubility in solute-rich supercritical fluids in the $KAlSi_3O_8 - H_2O$ system (representing K-rich fluids derived from subducted sediments) at 2.0-6.0 GPa and 800-1000ºC, close to the top-slab conditions at sub-arc depths. ZrO_2 solubility at zircon saturation in the supercritical $KAlSi_3O_8 - H_2O$ fluids linearly increases with solute content. Addition of K_2O to this system at 2.0 GPa or crystallization of Al-rich phases muscovite and kyanite at 4.0 and 6.0 GPa strongly enhance the solute alkalinity (molar K/Al) and ZrO_2 solubility. In particular, crystallization of kyanite at high pressures plays a key role in elevation of the solute alkali/Al ratio, leading to a reverse of the solubility from the negative effect of pressure to the positive effect of alkalinity at 6.0 GPa. Kyanite crystallization during deep subduction thus profoundly influences the alkali/Al ratio, zircon solubility and element carrying capacity of fluids.